INVENTIONS & INNOVATION

Project Fact Sheet

Electrocaloric Materials for Room Temperature Refrigeration

Benefits

- Will potentially save 50 kWh per year in a typical refrigerator using 1000 kWh per year
- Introduces energy-efficiency improvements with worldwide applications
- Explores the electrocaloric effect, a novel solid-state effect for refrigeration near room temperature
- Takes advantage of the ease and lower cost associated with electrical fields versus magnetic fields
- Needed dielectric insulations and voltage-handling circuitry are already well-established
- Could lead to cooling elements in the form of multilayer ceramic capacitors capable of being produced by existing, inexpensive manufacturing techniques
- Potentially no CFCs or CFC replacements used

Applications

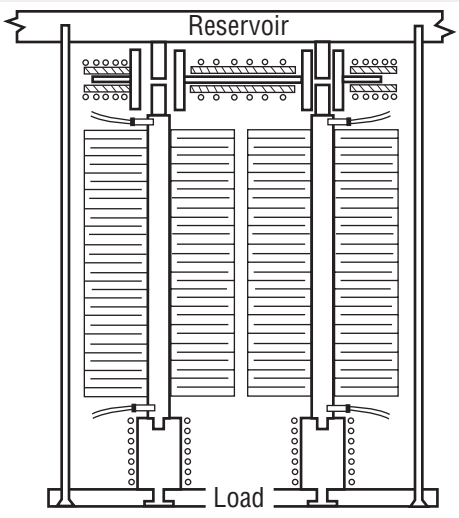
Initial applications for the new material will be as an active regenerator in a Stirling-type, split-cycle refrigerator and possibly in an all-solid-state refrigerator, both of which represent new generations of room temperature refrigeration technology.

New technology in refrigeration offers significant opportunity to reduce energy consumption

Home refrigerators and freezers consume a great deal of electricity and efforts to reduce energy consumption by improving refrigeration efficiency have been the focus of research over the last 25 years. Through the development of improved motors, compressors, and seals, as well as the introduction of microprocessors, these efforts have reduced annual electrical consumption by refrigerators and freezers in the United States from 1,750 kWh per year in 1970 to 750 kWh per year in 1992. Ongoing research to further improve efficiency has focused on the refrigeration cycle, with particular attention to the Stirling cycle and solid- state magnetic refrigeration. However, cost and reliability concerns continue to override technological advances in these areas, and no major breakthroughs have been made.

Recent work by scientists in Russia, however, has opened the door to a second opportunity in solid-state technology. Analogous to magnetic refrigeration, which cyclically applies a magnetic field to a paramagnetic solid to cause heating and cooling (the magnetocaloric effect), a new technology is based on the electrocaloric effect, whereby an electric field is cyclically applied to a paraelectric solid to cause heating and cooling. The key difference between the two approaches is that large electrical fields are much easier and less expensive to produce than magnetic fields. If advantages can be confirmed through continued research and development, industry will once again have the opportunity to substantially reduce energy consumption by refrigerators and freezers.

Vertical Section of a Solid State Refrigerator



New membrane technology offers greater efficiency in ammonia refrigeration systems by removing noncondensable gases, such as air, during the refrigeration process.

Project Description

Goal: The project goal is to conduct further research into the use of electrocaloric effects in household refrigeration systems to verify the potential for reducing energy consumption.

The electrocaloric effect is a yet to be explored solid-state effect for improving refrigeration efficiency. Conventional wisdom has been that electrocaloric effects are too small to be of any practical significance in household refrigeration systems. However, recent work has demonstrated electrocaloric temperature changes of 2°C near room temperature for remarkably small electric fields.

CeramPhysics, Inc., of Westerville, Ohio, regarded for its work in electrocaloric research, testing, and measurement, quickly recognized the potential of the Russian research results. CeramPhysics believes temperature changes in the 20-30°C range may be feasible, but only through use of an enhanced combination of ceramic materials. CeramPhysics' success in identifying the optimum combination may lead to a new line of inexpensive, multilayer ceramic capacitors. The concept of electrocaloric refrigeration is bolstered by two key advantages: (1) applying substantial electrical voltages is easy relative to applying magnetic fields, and (2) the accompanying insulations and voltage-handling equipment are already well-established. In addition, it may be possible for an electrocaloric refrigeration system not to involve any CFCs or CFC replacements, a huge advantage relative to conventional Rankin-cycle refrigerators and freezers.

CeramPhysics, Inc., is developing this new technology with the help of a grant funded by the Inventions and Innovation Program in the Department of Energy's Office of Industrial Technologies.

Progress and Milestones

- CeramPhysics has successfully replicated the work performed in Russia and is entering into a series of proprietary experiments designed to identify one or more alternate ceramic compositions with an electrocaloric effect larger than that of the composition used in the Russian research.
- The technology is in the conceptual stage of new product development.

Economics and Commercial Potential

The energy-savings potential associated with the proposed research is dramatic. According to the Electric Power Research Institute, reducing the electrical consumption of the Nation's refrigerators and freezers by just 4.2 percent would save an estimated 479 million kWh—the equivalent of an average base-level power plant. At this rate, improving refrigerator and freezer energy efficiency by 50 percent (an achievable goal under the proposed research) would save 12 new base-level plants.

With this potential for energy savings, the technology's commercial potential is highly promising. To take advantage of this potential, however, the technology must progress successfully through its development plan. The most pressing near-term challenge is to develop and demonstrate the effectiveness of selected combinations of ceramics.

CeramPhysics has already developed a detailed plan for meeting this challenge. In recognition of the leading-edge work previously performed abroad, CeramPhysics will maintain its relationship with these scientists to take advantage of their unique knowledge and experience. CeramPhysics has also attracted the interest of a key United States industrial partner that has agreed to underwrite a significant portion of this early-stage research. If the research results are as promising as expected, CeramPhysics and its partner will continue their cooperative arrangement for the purpose of commercializing the technologies developed.

The Inventions and Innovation Program works with inventors of energy-related technologies to establish technical performance and conduct early development. Ideas that have significant energy savings impact and market potential are chosen for financial assistance through a competitive solicitation process. Technical guidance and commercialization support are also extended to successful applicants.

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